



ASSESSMENT OF DAYLIGHT IN THE SELECTED OFFICE THROUGH SIMULATION PROGRAMS: A CASE STUDY

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Abstract: An important aspect of building design is to let the daylight into rooms and create a visual comfort. Visual comfort is a psychophysical condition needed for efficient work and rest, complying with the hygienic requirements, and depends on luminous intensity, illuminance, architectural design of the space, and eyes condition. Natural light increases productivity, improves mood, and helps to save energy and workers must feel a connection with the exterior environment. The room is lit by daylight through a window on the outside wall. The results show that a zone with sufficient illumination reaches only about one third of the depth of the place where both places are located. Furthermore, evaluation of different positioning of the table revealed that only one of the investigated areas was suitable, with good visual comfort and no glare.

Keywords: lighting conditions; office; computational simulation; daylight factor; indoor environment

PROCJENA DNEVNOG SVJETLA U ODABRANOM UREDU PROGRAMOM SIMULACIJE: STUDIJA SLUČAJA

Sažetak: Važan dio projektiranja zgrada je pustiti dnevno svjetlo u prostore i stvoriti vizualnu udobnost. Vizualna udobnost je psihofizičko stanje ugone koje je potrebno za učinkovito održavanje higijene rada i odmora, što ovisi o intenzitetu svjetlosti, razini osvijetljenosti, arhitektonskom oblikovanju prostora i stanju vida. Prirodno svjetlo povećava produktivnost, poboljšava raspoloženje i štedi energiju, a djelatnicima daje osjećaj povezanosti s vanjskim prostorom. Prostorija je osvijetljena dnevnim svjetlom kroz prozor vanjskog zida. Rezultati pokazuju da zona s dovoljno osvijetljenja dopire samo do trećine dubine prostora gdje se nalaze oba promatrana mjesta. Nadalje, ocjenjivano je različito pozicioniranje stola u prostoriji. Na temelju rezultata, samo je jedna od promatranih pozicija prikladno osvijetljena. U toj poziciji nije bilo blještanja i postignuta je dobra vizualna udobnost.

Cljučne riječi: uvjeti osvijetljenja; ured; računalna simulacija; faktor dnevne svjetlosti; unutarnji okoliš



1 INTRODUCTION

Daylighting a building means introducing the natural light into a building. To maximize the benefits of the natural light, it is vital to expand the interpretation of day lighting. A building's holistic energy strategy should include producing interiors that truly work for owners and occupants rather than it being a question whether to include the day lighting measures [1].

Unmanaged direct sunlight can cause disruptive or disabling glare, may lead to an overreliance on the air-cooling systems, increase the energy usage and running costs, and cause low humidity and uncomfortable air quality [1].

Layouts need to be designed to balance the artificial and the natural light, taking into consideration the façade reflection, the sun's movement, the glare, the shading, the light intensity and the automation. It ensures that the spaces are evenly lit, there is good patternation, and the external and the internal elements work together.

Most importantly, the lighting needs to suit the functions and the needs of the occupants. Offices on the hand have different specific requirements [1].

Quality of day lighting and the correct selection of materials to provide controlled natural day lighting are therefore essential. Daylighting is the practice of allowing a controlled amount of natural light into a building to reduce electric lighting costs. Adequate levels of daylight throughout the day are not always possible due to the ever-changing position of the sun, window orientation, and other factors. This is where a greater understanding of daylight design comes in [2, 3].

A day lighting system includes skylights and windows along with a daylight-responsive lighting control system. Such a system can reduce energy costs by as a much as 33%. Along the passage of light through the atmosphere, some wavelengths are absorbed by oxygen, ozone, water vapors, and carbon dioxide [4, 5].

Figure 1 shows the observed spectral distribution of sunlight on earth. Highest thermal radiation from the sun is observed at 550 nm wavelength.

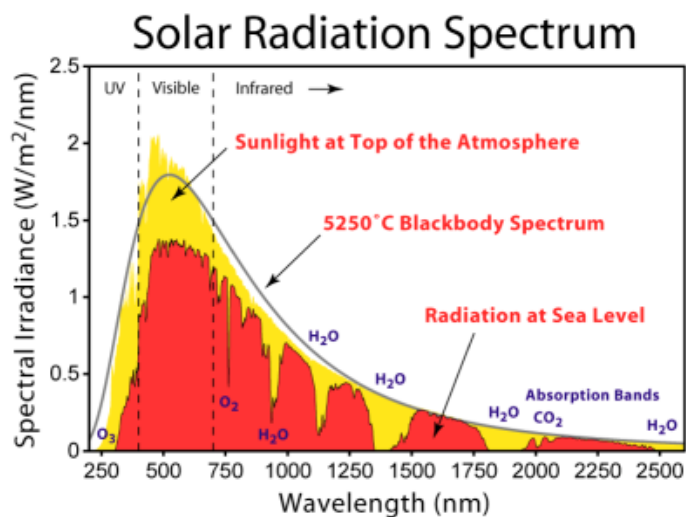


Figure 1 Spectrum of solar radiation [6]

In this study, the selected office was investigated and different positions were evaluated in terms of daylight and glare. The optimal position of the place was then evaluated by simulation in terms of both daylight and visual comfort.

2 DAYLIGHT REQUIREMENTS IN INTERNAL SPACES

The quantitative aspect of daylight illumination means enough daylight for securing visual activity. The quantitative level of daylight is expressed by the daylight factor [6, 7].

Daylight factor is the ratio of the internal light level to the external light level (see Figure 2):

$$DF = \frac{\text{Internal illuminance}}{\text{External illuminance}} * 100\% \quad (1)$$



The Daylight factor is a combination of three separate components (see Figure 3) [6]:

- The sky component – the light received directly from the sky (SC)
- The externally reflected component – the light received directly by reflection from the buildings and the obstructions outside the room (ERC)
- The internally reflected component – the light received from the surfaces inside the room (IRC)

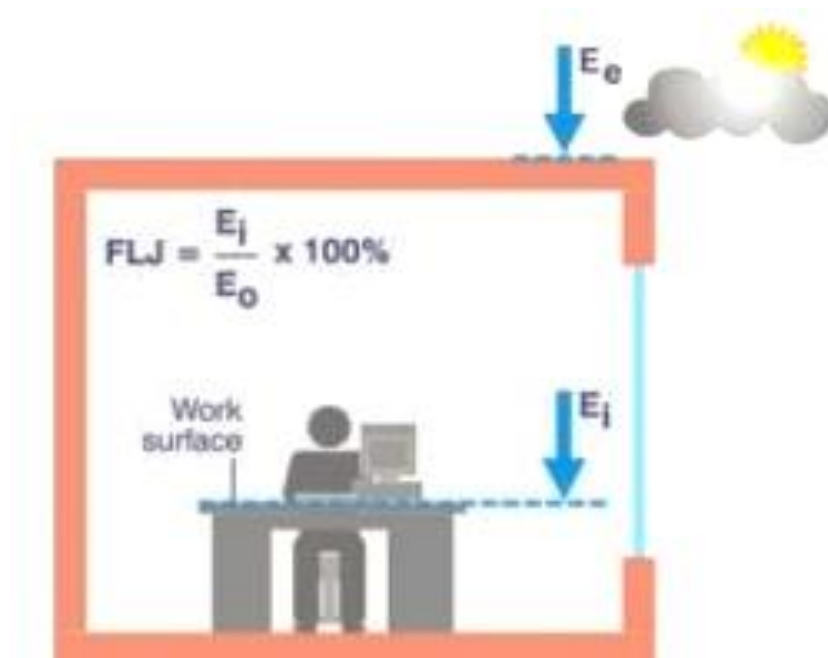


Figure 2 Daylight factor [6]

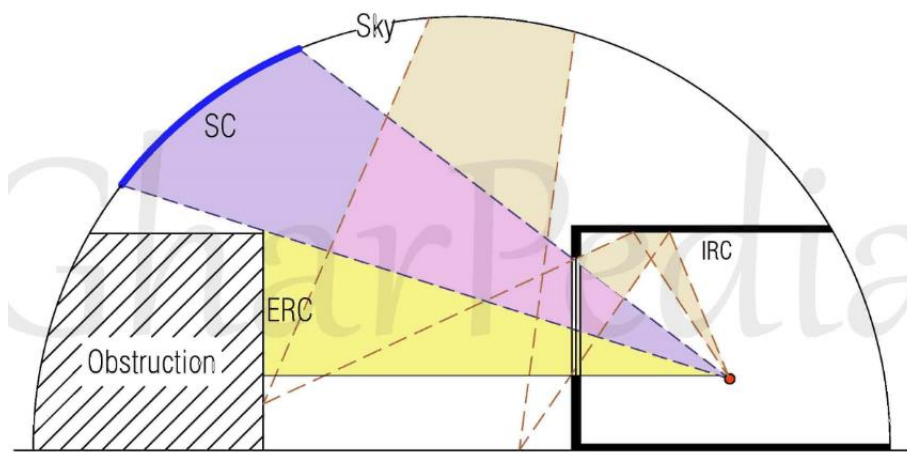


Figure 3 Sources of Daylight at a point within a room [7]

The classification of the internal day lighting indoor environment, according to Slovak and Czech's technical standards, is based on the work, its complexity, and the basic requirements placed on the complexity of the visual activity (see Table 1) [8-10].

**Table 1 Classification of human eye recognition of visual detail tasks [10]**

Human eye recognition category	Visual detail tasks
Extreme accuracy	The most accurate visual work with a limited use of magnification, a requirement to eliminate errors in definition, stringent control
High accuracy	Very precise activities involving production and control, high-precision drawing, hand engravings with very fine detailing, fine art work
Precise operations	Precision manufacturing and inspection, regular drawing, technical drawing, laboratory, labour-intensive investigations, fine sewing, embroidery
Medium accuracy	Medium precision manufacturing and inspection, reading, writing (by hand and machine), routine laboratory work, examinations, treatments, using machines, thicker sewing, knitting, laundry, cooking class, reading, teaching cabinet, kitchen, surgery, office, meeting room, conference room
Low accuracy	Approximate works, manipulating objects and materials, food consumption and service, leisure activities, physical education, dining room, living room, lounge, hall, gymnasium, swimming pool, storage room, waiting room
Very rough work	Maintenance and cleaning, showering and washing, changing, walking on public roads, cloakroom, toilets, corridors
Only spatial orientation	Walking, material transport, storage of raw materials, supervision

Technical lighting requirements for daylight are specified by the standard STN 73 0580-1 Daylighting of buildings. Part 1: Essential requirements [11].

3 EXPERIMENTAL SETTING

Measurements were performed in a typical office room in Košice. A third floor south facing office was selected with interior dimensions 3.5 m x 5 m x 2.7 m and the height of the parapet 900 mm. The room had side lighting created by a window with dimensions 1200 mm x 2100 mm.

The fenestration systems are created by double plastic glass. For calculations, the following coefficients were considered (transmittance coefficient 0.8, maintenance factor of glazing on the exterior surface 0.9, maintenance factor of glazing on the interior surface 0.85, reflectance factor of ground 0.15 (dark ground)). The walls and the ceiling were white in color with a reflectance factor of 0.7 and the floor had a reflectance factor of 0.2. The working plane was 0.75 m high (desk height). Light loss coefficient due to window construction was $\tau = 0.63$. The neighboring objects at a distance did not shade the room.

The room being used for medium-precision production was classified in IV. light – technical class (see Table 1). With the given lighting system, at the critical point of the functional place on the horizontal plane, the following values are required: minimum standard value of daylight factor $D_{\min} = 1.5\text{--}2\%$, average daylight factor $D_{\text{average}} = 5\text{--}6\%$, and uniformity of the illumination more than 0.2–0.3 for given visual task. [9-12].

An illumination of minimum 300 lx is recommended for most of the room area meeting the target climate-based daylight factor and 500 lx for the areas where productive work is performed. On the selected days, the value of the outside light ranged from 6.500–8.000 lx in January, 7.500–10.000 lx in February–March, and 25.000 lx in April. Exterior horizontal illumination of 5000 lx was considered for the simulation program [13, 14].

Daylight measurements were performed according to Slovak standard “Measurements of day lighting.” The instruments used were two Data loggers, ALMEMO 2690-10A, and illuminance sensor ALMEMO FLA 623VL with the production number 15061543, accuracy of 5%, and reflection of 0.847. Luminance meter LS-110 was used to measure the luminance with an accuracy of 2%.

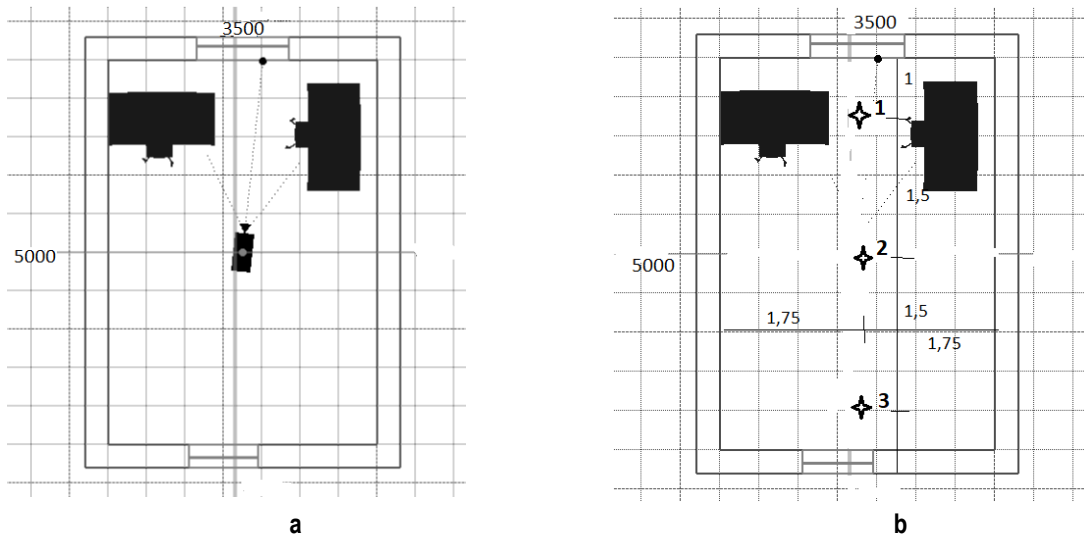


Figure 4 Plan of the test office room

3.1 Results

This article presents the measurement results for control point A (shown in Figure 4a) for three days in January (shown in Figure 6), for eight days in February–March (shown in Figure 11), and one day for points A and B and 1–3 (shown in Figure 4b) in April. The measured sky conditions rating the gradations of sky luminance in January are shown in Figure 5 (a, b) and for February and March are shown in Figure 5 (c, d). In Figure 5 x refers to the elevation angle, y refers to the Le/Lz ratio, Le refers to the external sky luminance, and Lz refers to the sky luminance at an angle of Z 15 °and 45°; (a) the beginning of measurements in January (b) the end of measurements in January (c) the beginning of measurements in February and March (d) the end of measurements in February and March.

For illuminance analysis, the Perez sky model was used in the software, using weather data as the source for sky condition information. Day lighting simulations were performed with Velux Daylight Visualizer 3. The results of illumination, DF lighting, and luminance calculated and can be seen in Figure 12 and 13.

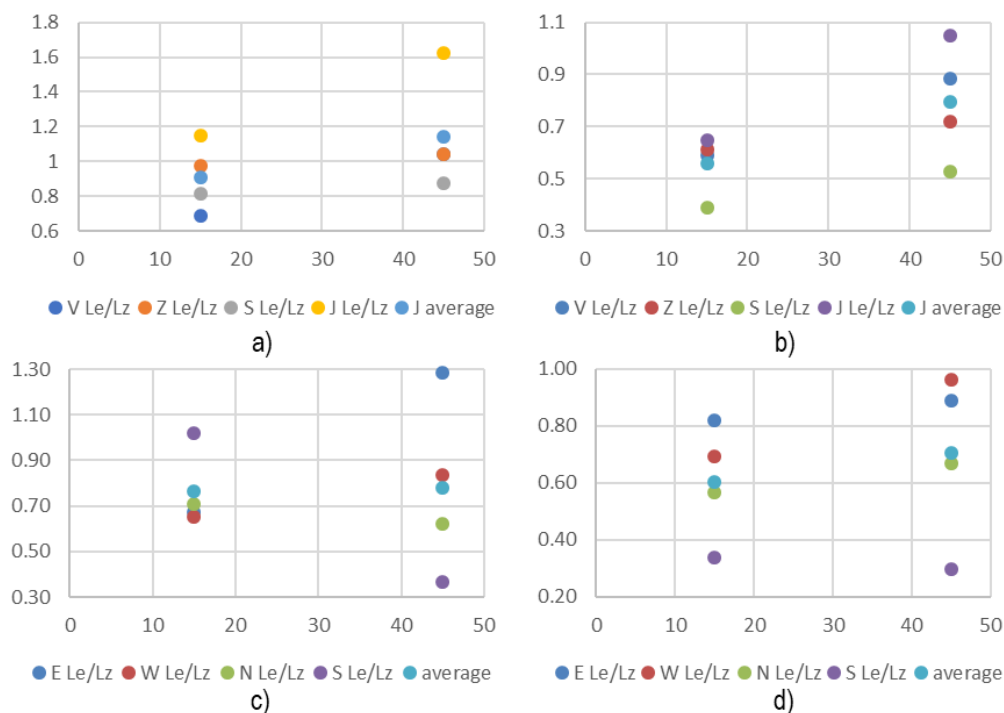


Figure 5 Measured sky conditions rating the gradations of sky luminance

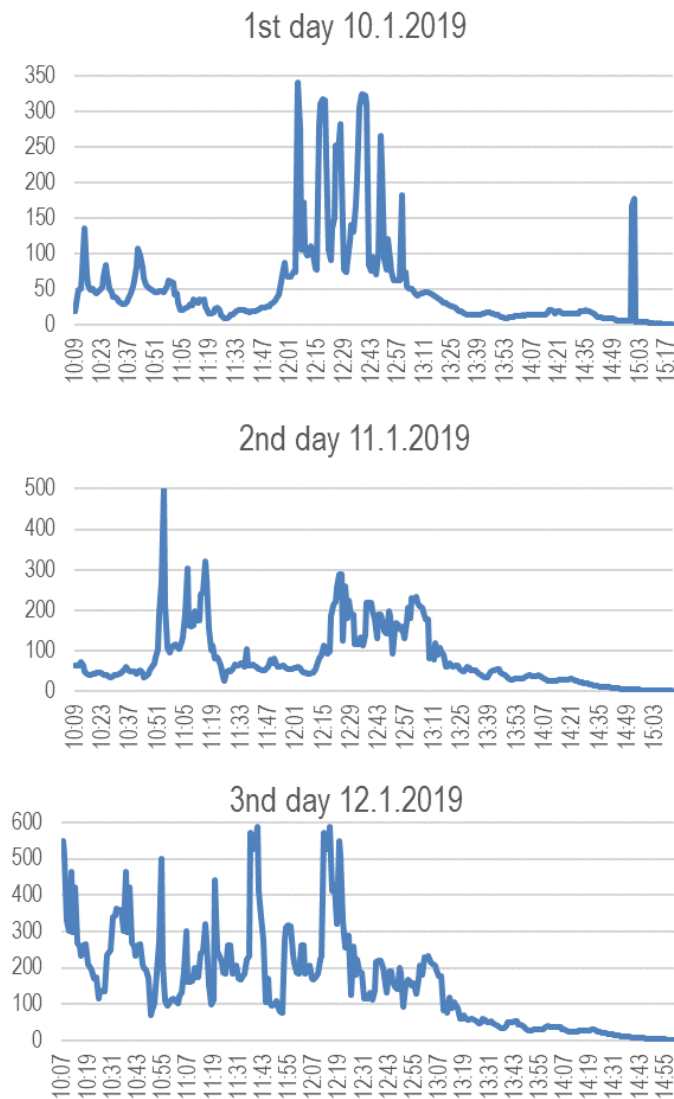


Figure 6 Measured values of illuminance level (lx) in January

Table 2 Calculated values from the measured values of Daylight factor (%) in January

1st day			
	D_{min}	D_{max}	$D_{average}$
10–12	0.12	2.09	0.61
12–13	0.95	5.25	2.31
13–15	0.05	2.72	0.32
2nd day			
	D_{min}	D_{max}	$D_{average}$
10–12	0.38	6.25	1.31
12–13	0.68	4.26	2.15
13–15	0.03	2.72	0.67
3rd day			
	D_{min}	D_{max}	$D_{average}$
10–12	1.06	7.36	3.39
12–13	1.34	7.36	3.21
13–15	0.03	3.34	0.66

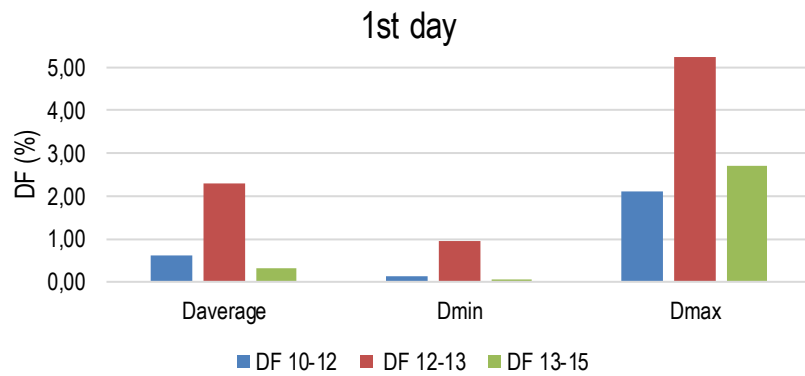


Figure 7 Graph of calculated values from the measured values of Daylight factor (%) in January

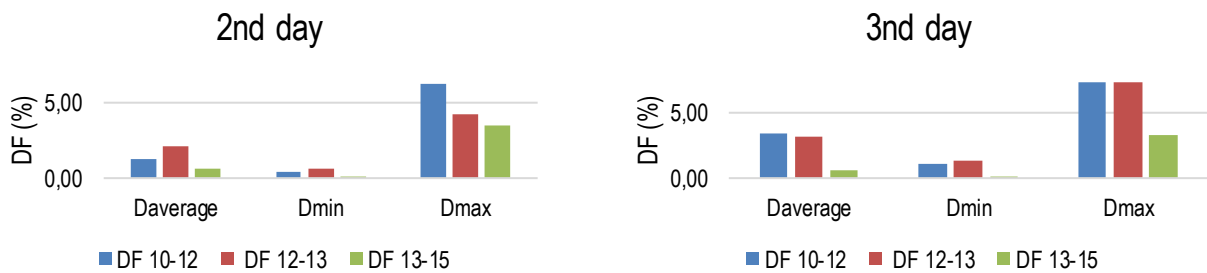


Figure 8 Graph of the calculated values from the measured values of Daylight factor (%; on selected days in January

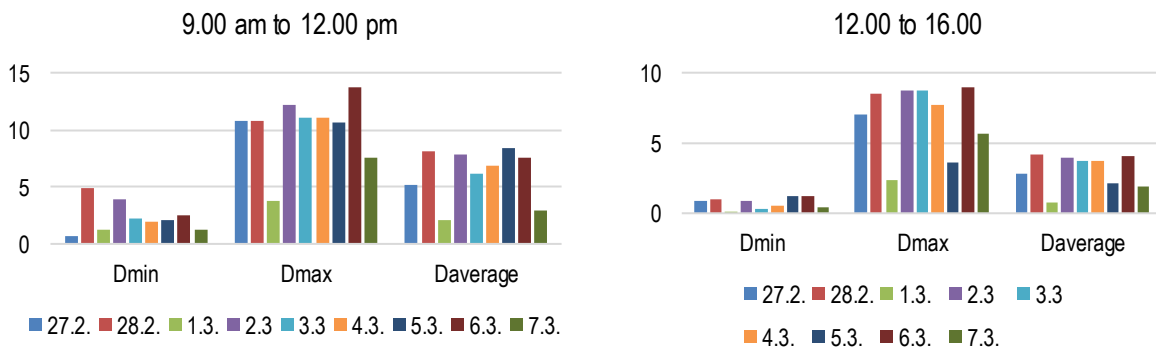


Figure 9 Calculated values from the measured values of Daylight factor (%) in February–March

Table 3 Calculated values from the measured values of Daylight factor (%) in April

Control point 1		
D_{min}	D_{max}	$D_{average}$
6.0	6.37	6.19
Control point 2		
D_{min}	D_{max}	$D_{average}$
0.86	1.72	1.2
Control point 3		
D_{min}	D_{max}	$D_{average}$
0.54	0.7	0.61



Table 4 Calculated values from the measured values of Daylight factor (%) in April

Control point A		
D_{min}		D_{max}
6.23		14.91
		$D_{average}$
		9.06

Control point B		
D_{min}		D_{max}
1.60		1.96
		$D_{average}$
		1.74

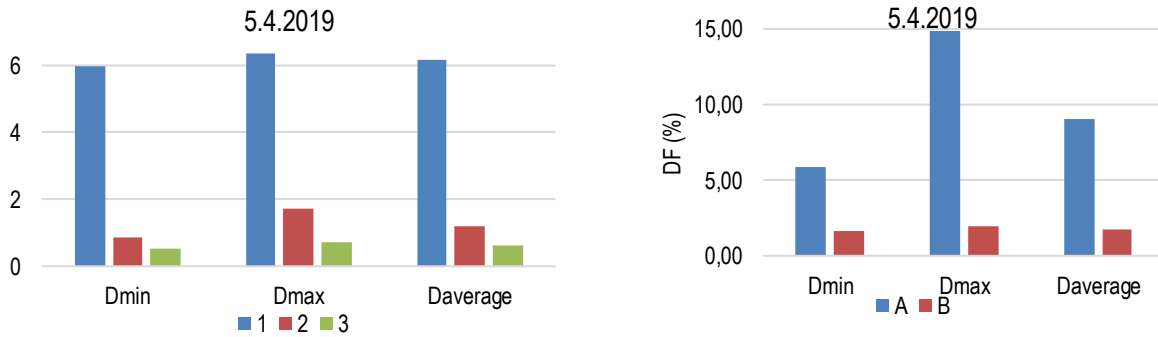
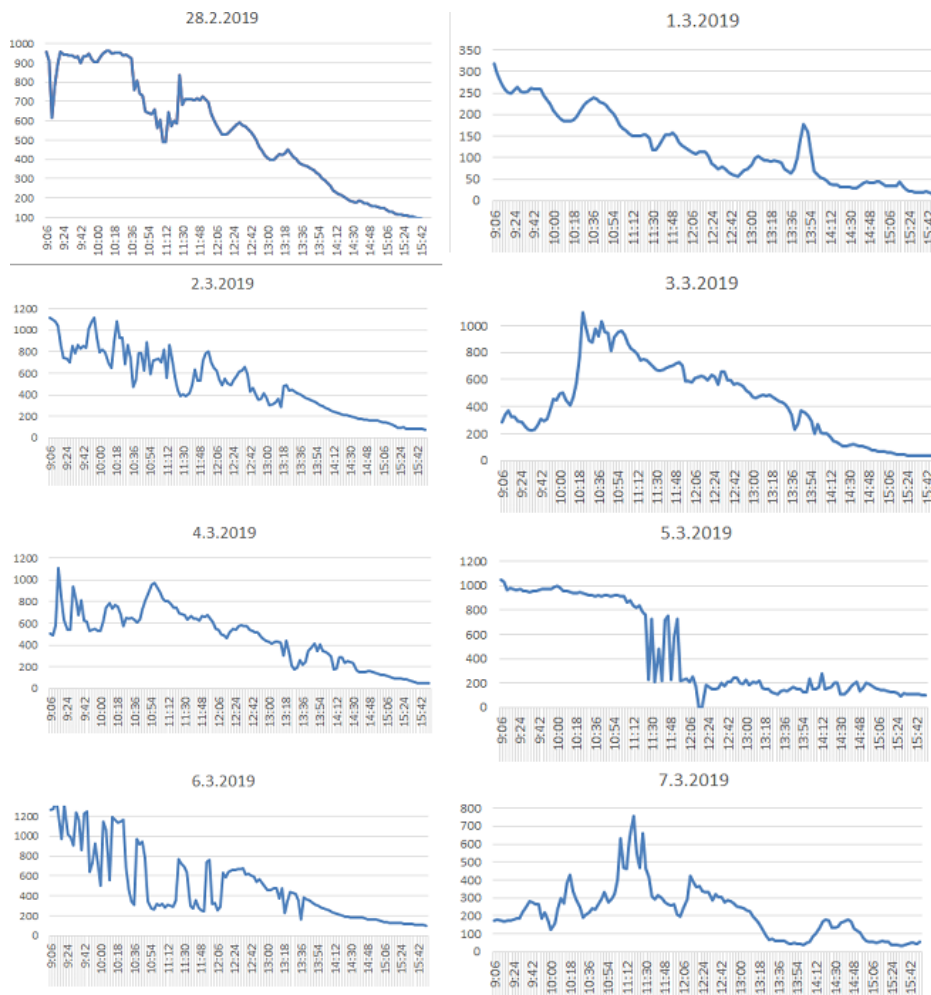
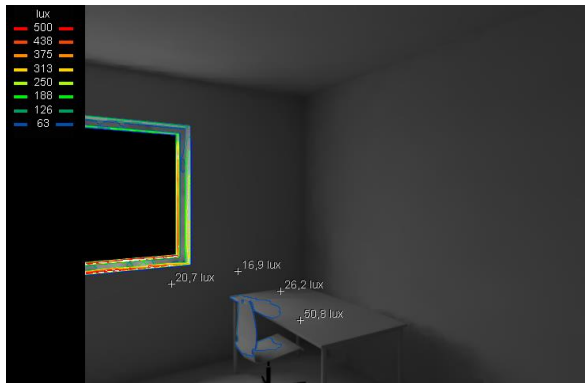
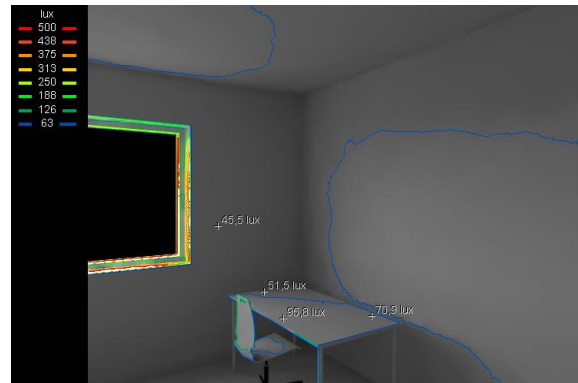


Figure 10 Calculated values from the measured values of Daylight factor (%) in April





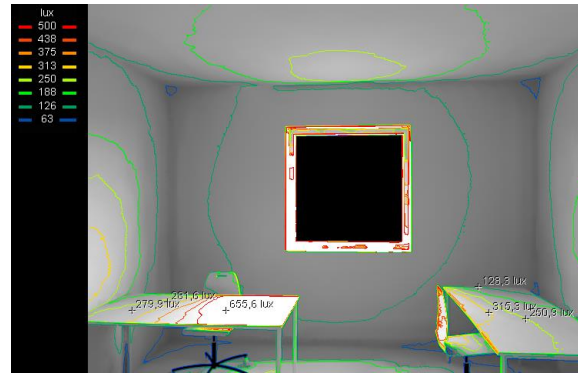
a - overcast sky, southeast view - point A; January



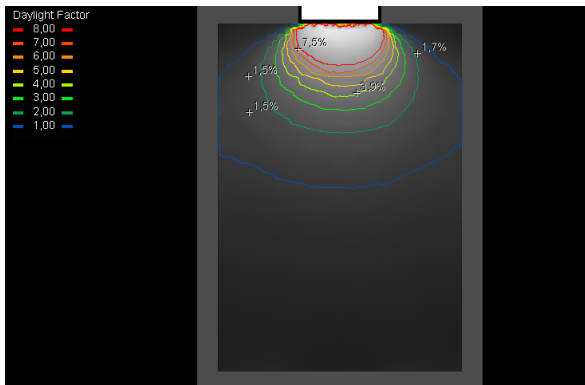
b - sunny sky, southeast view - point A; January



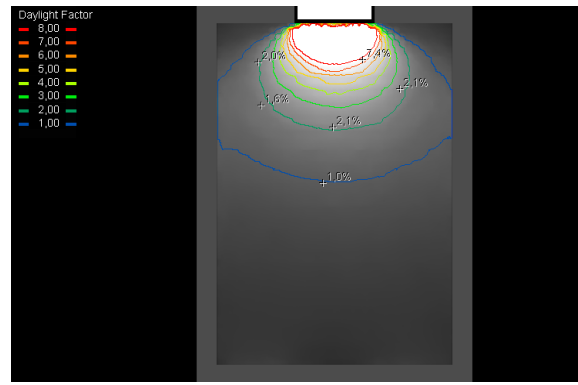
c - overcast sky, south view - points A and B; April



d - sunny sky, south view - points A and B; April



e - overcast sky, southeast view - point A



f - overcast sky, south view - points A and B

Figure 12 Results of illumination (lx) and Daylight Factor (%)

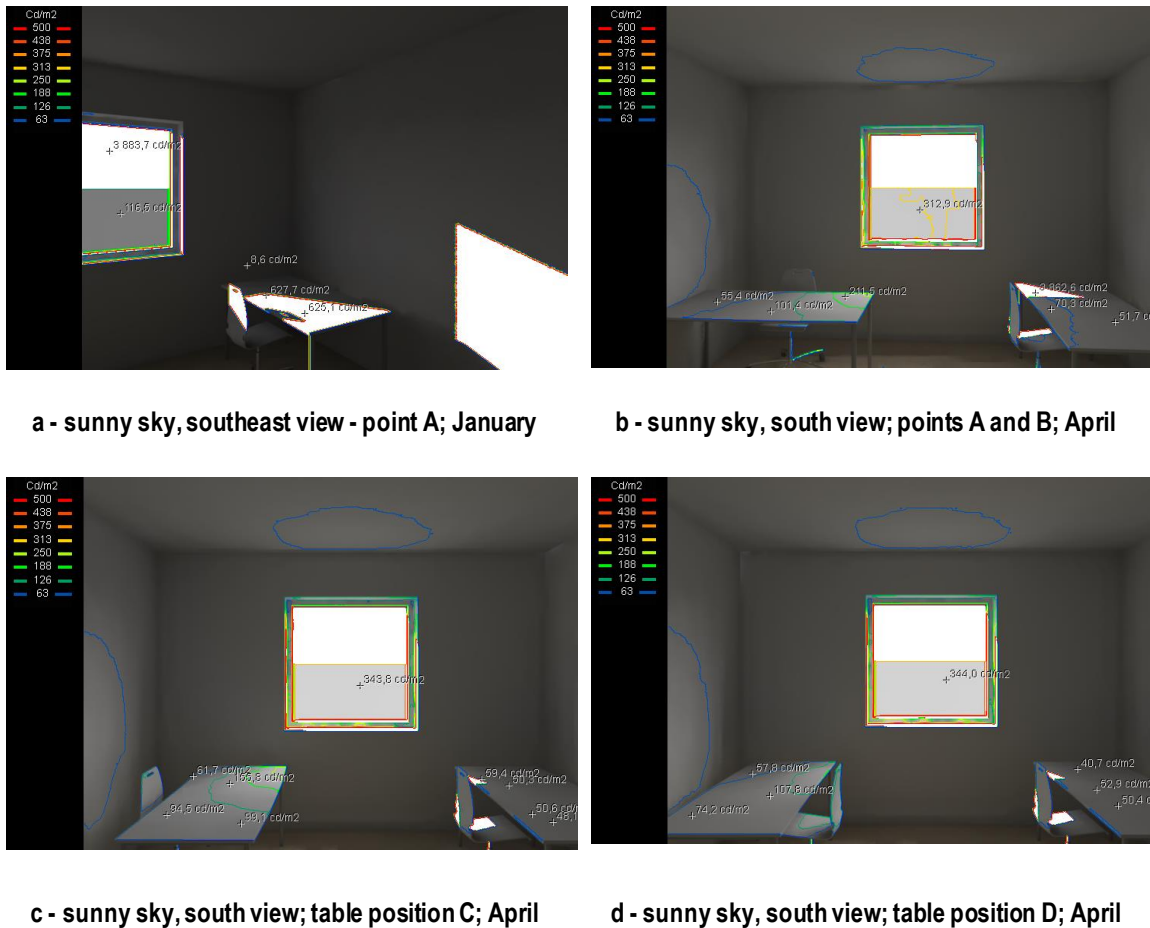


Figure 13 Results of luminance level (cdm²)

4 CONCLUSION

The provision of natural daylight within the built environment can deliver genuine and positive benefits to the finished construction; benefits that can enhance the financial and environmental performance of the building, benefits that can improve the internal environment and make it a better and more pleasant place. To stimulate the mind and improve concentration, it is important to have the area brightly lit [15,16].

The window in the tested room occupied about approximately 15% of the floor area. The measured sky conditions rating the gradations of sky luminance in January and February–March are shown in Figure 5 (according to standard ratio L_{θ}/L_z at 15° is 0.3–0.6 and at 45° is 0.7–0.85).

The results (Table 3, 4, and Figure 10, 12) show that a zone with sufficient illumination reaches only about one third of the depth of the place where both places are located. Comparing points A and B shows that point A has more light in terms of the quantity of light (it expresses the parameter DF). Glare occurs both at points A and B (Figure 13 a-b), especially in the morning; however they are suitable in the afternoon. Based on the results, the appropriate position of the PC can be determined by position C (Figure 13 c), that has good visual comfort and no glare. Positions A and B need glare protection in the morning (Figure 13 a-b). No work with PC can be performed in position D from 1 pm to 4 pm.



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